Phytoplankton ecology: irradiance, particles, gilvin, pigments, absorption, fluorescence, production and species density in Terra

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PHYTOPLANKTON ECOLOGY: IRRADIANCE, PARTICLES, GILVIN, PIGMENTS, ABSORPTION, FLUORESCENCE, PRODUCTION AND SPECIES DENSITY IN TERRA NOVA BAY, ROSS SEA

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INTRODUCTION

The first aim of this investigation was to examine more thoroughly the temporal distribution of phytoplankton biomass, production, and composition in Terra Nova Bay and the relationships between the phytoplankton and the main environmental factors such as solar irradiance, thermohaline structure of the water column and nutrients. We have also been interested to the ecology of the sea-ice microalgae for the complex relationships existing between water and sea-ice communities, both at the moment of the ice formation and of its melting and for the role of these microalgae in the whole primary production process (Ackley & Sullivan, 1994).

Our previous studies in the zone (Innamorati *et al.*, 1989; 1990a; 1990b; 1990c; 1991; 1992a; 1992b; 1994a; Lazzara & Nuccio, 1994; Lazzara *et al.*, 1995; 1996b; Nuccio *et al.*, 1992; 1994; Saggiomo *et al.*, 1992) did concern the spatial and temporal distribution of phytoplankton in relation to the main environmental factors. The most evident feature of the area emerging from the previous investigation is the spatial heterogeneity of phytoplankton biomass, ranging from oligotrophic to eutrophic conditions, that appears to be related to the temporal evolution of the phytoplankton community. This temporal trend seems to suggest the presence of two blooms in Terra Nova Bay, in early and in late summer (Innamorati *et al.*, 1992a). There is now some increasing evidence that the classical single peak bloom (El-Sayed, 1988), could be articulated into two distinct pulses, in the Western Ross Sea (Arrigo & McClain, 1994; Knox, 1994).

MATERIALS AND METHODS

Two ice free stations were sampled, at Terra Nova Bay (station Baia Terra Nova, ϕ=74°41'.700S, γ=164°07'.384E) nearshore with a depth of 2-3 m and at station Tiburtina (ϕ=74°42'.300S, γ=164°10'.050E) with a depth of 300 m. The sampling started on the 13.01.95 for St. Baia Terra Nova (BTN) and on the 21.01.95 for Tiburtina (TIB).

Two sampling stations were in the pack ice at Gerlache Inlet (st. Gerla, ϕ=74°40'.136, γ=164°06'.866E) and at Tethys Bay (st. Tethys, ϕ=74°41'.116S, γ=164°03'.563E). In these stations sampling has been carried out through a hole in the pack ice. Two different methods have been used to make the holes: at Tethys the ice has been broken into fragments which melted afterwards in the sea water; at Gerla the pack ice has been completely removed from the sea water. The sampling

period was between the 16.01.95 and the 08.02.95 at Tethys and between the 20.01.95 and the 05.02.95 at Gerla.

Samples of pack ice with sympagic microalgae have been collected at different depths: "bottom ice" from the pack ice during the perforation of the hole at Gerla on the 20.01.95; "surface ice" taking a piece of pack-ice fractured from the marginal ice zone at the sea level at Tethys Bay on the 08.02.95; "interior ice" by means of a pack ice corer in proximity of Campbell glacier tongue, on the 10.02.95.

Seawater samples have been collected by Niskin bottles, through the ice hole in the pack ice stations and from aboard of R/V *Malippo*", at surface and down to 150 m at TIB. At BTN seawater samples have been collected at the surface directly from the shore.

The concentration of liposoluble pigments (Whatman GF/F filters) was determined by means of:

- spectrophotometric analysis (Kontron Uvikon 930) for chlorophaeopigments (*chl* = chlorophyll *a* and phaeopigments), using the monochromatic equation (Jeffrey &Humphrey, 1975; see also Lazzara *et al.*, 1990 and Innamorati *et al.*, 1994b) and for total carotenoids according to Richards &Thompson (1952);
- spectrofluorometric analysis (Perkin Elmer LS5B) for chlorophyll *a* and phaeopigments, using purified chlorophyll *a* (SIGMA) as standard, and partially following Lazzara *et al.*, (1990), except for the calibration factors which have been obtained from a linear regression of fluorescence *vs* concentration (dilution series of three orders of magnitude).

Recording of continuous downwelling surface quantum PAR has been carried out by means a LI-COR LI-192SA cosine sensor coupled with a LI-COR LI-1000 data logger. The quantum PAR data have been acquired as averages every 10 minutes.

Underwater downwelling, upwelling, scalar and contemporary surface downwelling quantum PAR irradiance have been measured by means of a photoprobe (Innamorati *et al.*, 1994b) equipped with 3 cosine (LI-COR LI-192SA) and 1 spherical quantum meters (LI-COR LI-193SA).

Spectral irradiance at the sea surface and underwater at various depths in the euphotic layer has been measured by means of a LI-COR LI-1800-01 UW spectroradiometer. Time is indicated as local time (l. t.= GMT+11 hours).

Absorption coefficient spectra (m^{-1}) of dissolved organic matter (gilvin) have been measured by spectrophotometry, according to Bricaud *et al.* (1981), on Whatman GF/F filtered seawater, with 10 cm quartz cells; some samples have been analysed immediately after sampling and filtration, the others later in Italy, after fixation by $HgCl_2$.

The number of particles and their size spectra have been determined by means of a Coulter Counter Multisizer (140 μm orifice tube). The measurements have been carried out in Italy on samples fixed with Lugol at the final concentration of 1% and not on fresh samples (as in the previous, 1987/88 and 1989/90 campaigns). In Table 7 the total, corrected, particles number (N_{cor}/cm^3) in the size range 2.8-90.3 μm is reported. The particles number calculated as the integral of the value for each channel (N/cm^3) is reported in the size range 2.8-90.3 μm and for 3.5-42.3 μm, the volumes in $\mu m^3/mm^3$ (ppb or 10^{-9} vol/vol) are also reported. Only the first particles number (N_{cor}/cm^3) is comparable with data of the previous reports (Innamorati *et al.*, 1990b; Innamorati *et al.*, 1994a).

Measurements of the *in vivo* absorption spectra were performed, by a spectroradiometer (LI-COR LI-1800-01 UW) with integrating sphere (LI-COR LI-1800-12S), collecting the particulate with gentle filtration on Whatman GF/F filters (∅ 25 mm) soaked with filtered seawater. The absorption spectra of depigmented material were measured on the same filters extracted for 24 hours in pure methanol at 4°C (Kishino *et al.*,1986) and soaked again. Phytoplankton absorption spectra were calculated subtracting the depigmented material spectra from the particulate ones. After that, the spectra have been blank subtracted and corrected for the pathlength amplification (β factor) following Bricaud & Stramski (1990).

Fluorescence has been measured, for the same samples as for absorption, directly on suspensions in 1 cm cuvettes, using a spectrofluorometer (Perkin-Elmer LS5B) equipped with a red sensitive photomultiplier tube and a quantum correction device (rhodamine B) which allows fluorescence excitation spectra to be corrected up to 630 nm. The measurements have been performed at 440 nm for excitation and 684 nm for emission before (F_0) and after addition of the photosynthesis inhibitor DCMU (final concentration 20 μM) and 1 min of exposure to saturating irradiance (F_{max}), so that variable fluorescence (F_v=F_{max}-F_0) could be calculated. In most cases also spectral values have been measured on samples concentrated by gentle filtration in dim light on a 0.22 μm Nuclepore filter with continuous resuspension of the sample. This concentration procedure has been necessary to record the entire spectra with sufficient accuracy. Finally the spectra have been scaled to the signals measured at single λ, see also Lazzara *et al.*, (1996a) for further details on the procedure.

Primary production has been measured according to the integral production method (Rieman & Moller Jansen, 1988). The samples (50 cm^3) have been inoculated with 10 μCi of $NaOH^{14}CO_3$ and incubated on deck for 3 or 7 hours around local noon at different irradiance levels obtained with 3 different neutral density filters (T=40%, 8% and 1.3%) and, at the lower irradiance, coupling the incubation flasks one over the other up to five, with T≈80% for a flask. Every sample of 50 cm^3 has been subsampled in two 20 cm^3 samples and analysed by liquid scintillation.

Measurements of F_0, F_{max} and then F_v have been carried out in the same samples as for primary production, before and after the incubation period. The variable fluorescence F_v has also been measured for a Fe-enrichment experiment, in natural samples with iron addition (Fe^{3+} citrate in EDTA) at a final concentration of 0.012 μM, after 24, 48, 72 h of incubation time.

Phytoplankton samples have been fixed in formaldehyde at final concentration of 3% for microscopic analysis with Zeiss invertoscope IM35 (40x). For species identification the following taxonomic texts have been used: Balech (1976); Chrétiennot-Dinet (1990); Hasle (1964, 1965a, 1965b); Manguin (1960); Medlin & Priddle (1990); Priddle & Fryxell, (1985); Ricard (1987).

PRELIMINARY OBSERVATIONS

- Phytoplankton pigments concentration at St. BTN — Tab. 1
- Pigments specific absorption coefficient spectra of acetone extracts at BTN — Figg.1-3
- Phytoplankton pigments concentration at St. TIB — Tab. 2
- Pigments specific absorption coefficient spectra of acetone extracts at TIB — Figg. 4-6
- Phytoplankton pigments concentration at St. Tethys — Tab. 3

- Pigments specific absorption coefficient spectra of acetone extracts at Tethys Fig. 7
- Phytoplankton pigments concentration at St. Gerla Tab. 4
- Pigments specific absorption coefficient spectra of acetone extracts at Gerla Fig. 8
- Pigments concentration in the sea ice Tab. 5
- Dissolved organic matter absorption coefficient (440 nm) Tab. 6
- Particles density and volume Tab. 7
- Particles volume spectra at St. BTN Fig. 9
- Particles volume spectra at St. TIB Figg. 10, 11
- Particles volume spectra at St. Tethys Figg. 12, 13
- Particles volume spectra at St. Gerla Fig. 14
- Variable fluorescence measurements Tab. 8
- Primary production and variable fluorescence Tab. 9
- Fe experiment: variable fluorescence measurements Tab. 10
- Surface phytoplankton density at St. BTN Tab. 11-13
- Surface phytoplankton density at St. TIB Tab. 14,15
- Continuous surface quantum PAR records Fig. 15
- Quantum PAR vertical profiles Fig. 16
- Underwater irradiance spectra at St. TIB Fig. 17
- Underwater irradiance spectra at St. Tethys Fig. 18
- Underwater irradiance spectra at St. Gerla Fig. 19
- Absorption coefficient spectra of particulates, detritus and phytoplankton at TIB Figg. 20, 21
- Absorption coefficient spectra of particulates, detritus and phytoplankton of ice samples Fig. 22
- Fluorescence excitation spectra at St. TIB Fig. 23
- Fluorescence excitation and emission spectra of ice samples Fig. 24
- Vertical profiles of chlorophyll a + phaeopigments at St. TIB Fig. 25
- Temporal distributions of surface *chl* and cell density Fig. 26

The temporal distribution of phytoplankton biomass (Fig. 26) has been followed: both cell density and chlorophyll roughly follow the same trend of the previous years (Innamorati *et al.*, 1992a). The first bloom previously registered at the end of December now appears shifted to the first half of January and the beginning of the second one is shifted to the first week of February. The first bloom occurs when the irradiance has reached the maximum (Fig. 15) and enough energy has been collected to melt the pack-ice, to warm and stabilise the surface layer of the water column (Lazzara *et al.*, 1996b) and to allow a high primary production level. Afterwards the biomass rapidly decreases to reach the lowest value at the end of the January but, in February the trend inverts towards an increase.

In stratified conditions there is also evidence for a strong nutrients depletion in the euphotic layer (Lazzara *et al.*, 1996b), the replenishment of nutrients from the deeper waters leads to a second late summer bloom, being the solar irradiance still high (Fig. 15). Even the primary production measurements did show high ^{14}C assimilation rates (Tab. 9), in late summer.

Photoinhibition processes have also been observed in the surface layer, in stratified conditions. Interestingly, in such conditions, surface samples have revealed the presence of a compound with extremely high absorption in the UV-VIS boundary domain (375 nm) in the acetonic extracts (Figg. 4-6). In some of these samples the

increase of absorption is not related to an enhanced photosynthetic activity compared with the deep samples as revealed by the *in vivo* fluorescence of chlorophyll *a* (Fig.23), a photoprotective role is therefore hypothesised for this substance.

From microscopic observations, surface phytoplankton densities (Tabs. 11-15; Fig. 26 a, b) show the highest values during the second half of January and around the middle of February (up to 9000 cell/cm^3). Generally, pennatae diatoms are dominant but there is also evidence for a noticeable presence of nanoplanktonic phytoflagellates.

The microalgal biomass of the ice assemblages sampled in different ice environments are similar and exceptionally high from 100 to 200 10^6 cell/dm^3 (Lazzara *et al.*, 1995) and from 1000 to 8000 mg/m^3 of chlorophyll (Tab. 5) and the highest value are reached in the bottom ice. The floristic composition of the ice assemblage appears to be very differentiated (Lazzara *et al.*, 1995). The bottom ice is dominated by long chain forming *Amphiprora* cfr. *kufferathii* while the interior ice microalgal cells essentially belong to genus *Nitzschia* and the surface assemblage is exclusively dominated by a benthic diatom (*Navicula* sp.). The potential photosynthetic activity of these microalgae is present, even if very low ($F_v/F_{max} \approx$ 0.1), only in the surface ice assemblage (Tab. 8). Extremely high phototrophic productions (up to 550 mgCm^{-3} hr^{-1}) but low assimilation numbers (0.45 mgC/mgchl h) are evident from ^{14}C measurements, even in the late summer (Tab. 9).

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Station BAIA TERRA NOVA

Date	m	Chl a	Phaeop.	Chl a + Phaeop.	Chl (monochr.)	Caroten.
14/01/95	0	4.453	3.615	8.068	5.054	-
15/01/95	0	2.397	1.719	4.116	2.196	-
16/01/95	0	1.347	2.002	3.350	2.452	0.354
17/01/95	0	1.552	2.049	3.600	2.680	0.381
18/01/95	0	2.392	1.857	4.250	3.821	0.354
19/01/95	0	1.808	3.678	5.485	4.106	0.381
20/01/95	0	0.521	0.915	1.435	1.118	0.354
21/01/95	0	0.705	0.937	1.643	1.494	0.810
22/01/95	0	0.602	0.560	1.162	0.992	0.746
23/01/95	0	0.789	1.021	1.810	1.403	1.117
24/01/95	0	1.952	1.840	3.792	3.331	2.399
25/01/95	0	1.481	1.438	2.919	2.395	1.731
26/01/95	0	0.814	1.268	2.083	1.699	1.275
27/01/95	0	1.084	1.361	2.445	1.688	1.426
29/01/95	0	1.185	1.518	2.703	1.985	1.177
30/01/95	0	0.502	0.921	1.424	0.878	0.609
31/01/95	0	1.556	1.376	2.932	2.372	1.893
01/02/95	0	1.639	1.587	3.226	2.532	1.631
02/02/95	0	0.652	0.800	1.452	1.323	0.888
03/02/95	0	0.683	0.988	1.671	1.255	0.858
04/02/95	0	0.709	1.159	1.868	1.323	0.796
05/02/95	0	0.853	1.287	2.140	1.563	0.838
06/02/95	0	0.601	0.972	1.573	1.084	0.595
07/02/95	0	1.163	1.197	2.360	1.585	0.891
08/02/95	0	0.555	0.471	1.026	0.764	0.146
09/02/95	0	0.885	0.671	1.555	1.198	0.709
10/02/95	0	0.512	0.504	1.016	0.707	0.451
11/02/95	0	0.345	0.310	0.654	0.489	0.312
12/02/95	0	0.729	0.527	1.255	0.970	0.591
14/02/95	0	0.482	0.447	0.929	0.573	0.458
15/02/95	0	2.357	2.107	4.464	3.062	2.488
16/02/95	0	1.634	1.098	2.732	2.304	1.770
17/02/95	0	0.965	0.767	1.732	1.312	1.281
18/02/95	0	1.372	0.881	2.253	1.922	1.638
19/02/95	0	0.653	1.066	1.718	1.167	1.056

Tab. 1 - Phytoplankton pigments concentrations (mg/m^3) at BTN

Station TIBURTINA

Date	m	Chl a	Phaeop.	Chl a + Phaeop.	Chl (monochr.)	Caroten.
21/01/95	0	0.529	1.103	1.632	0.970	0.890
22/01/95	0	0.066	0.296	0.362	0.106	0.078
	5	0.218	0.605	0.824	0.433	0.355
	10	0.118	0.440	0.558	0.171	0.154
	19	0.663	1.366	2.028	1.471	1.046
	25	0.920	1.464	2.384	1.802	1.150
	50	0.625	1.035	1.660	1.357	0.699
	70	0.372	0.783	1.155	0.981	-
	100	0.546	0.644	1.191	0.935	-
	150	0.234	0.333	0.567	0.388	-
24/01/95	0	1.283	1.332	2.614	2.133	1.863
	5	1.156	1.193	2.349	2.110	1.902
	10	1.537	2.212	3.749	3.045	2.650
	12	1.374	2.192	3.566	2.794	2.548
	25	0.749	1.704	2.453	1.825	1.042
	50	1.217	1.441	2.658	2.327	1.485
	70	0.939	1.935	2.873	1.996	1.201
	100	1.086	1.814	2.900	2.213	1.418
	150	0.359	0.551	0.910	0.582	0.401
26/01/95	0	1.024	2.007	3.031	1.985	1.687
	5	0.673	1.774	2.447	1.551	1.382
	10	0.811	1.564	2.374	1.642	1.476
	25	0.553	1.255	1.807	1.152	0.709
	50	0.304	0.940	1.244	0.673	0.334
	70	0.874	1.151	2.025	1.582	0.918
	100	0.447	0.960	1.407	1.015	0.609
	150	0.400	0.551	0.951	0.741	0.474
28/01/95	0	0.918	1.335	2.253	1.449	1.274
	5	1.387	1.895	3.282	2.087	1.744
	10	1.131	2.229	3.360	2.144	1.415
	19	0.935	1.762	2.697	1.779	1.170
	25	0.970	1.794	2.764	1.802	1.159
	50	0.998	2.151	3.149	1.757	1.248
	70	0.954	1.706	2.660	1.985	1.122
	100	0.521	0.775	1.295	0.867	0.536
	150	0.628	0.863	1.491	1.015	0.630

Tab. 2 - Phytoplankton pigments concentrations (mg/m^3) at TIBURTINA

Station TIBURTINA

Date	m	Chl a	Phaeop.	Chl-*a* + Phaeop.	Chl (monochr.)	Caroten.
02/02/95	0	0.801	1.056	1.857	1.483	0.941
	10	0.629	1.236	1.865	1.346	0.848
03/02/95	0	0.529	0.835	1.364	0.935	0.704
	5	0.646	1.291	1.938	1.437	0.860
	10	0.663	1.430	2.093	1.460	0.931
	25	0.729	1.529	2.258	1.540	0.834
	30	0.520	1.398	1.918	1.163	0.648
	50	0.636	1.305	1.941	1.540	0.841
	70	0.438	0.675	1.113	0.833	0.404
	100	0.459	0.944	1.404	1.015	0.457
	150	0.443	0.667	1.110	0.798	0.372
04/02/95	0	0.498	1.074	1.572	1.061	0.625
	10	0.833	1.740	2.572	1.802	1.134
08/02/95	0	0.406	0.537	0.944	0.616	-
09/02/95	0	0.498	0.686	1.184	0.787	0.480
	10	0.552	0.853	1.405	0.947	0.555
10/02/95	0	0.820	0.818	1.738	1.385	0.666
	5	0.465	0.698	1.162	0.780	0.455
	10	0.376	0.635	1.010	0.668	0.451
	25	0.448	0.782	1.231	0.657	0.444
	50	0.460	0.821	1.280	0.708	0.440
	70	0.482	0.614	1.095	0.623	0.414
	100	0.468	0.535	1.003	0.591	0.347
	150	0.187	0.852	1.039	0.297	-
12/02/95	0	0.220	0.247	0.466	0.303	0.224
	5	0.441	0.534	0.975	0.631	0.413
	10	0.370	0.376	0.746	0.504	0.363
	25	0.345	0.379	0.725	0.484	0.334
	50	0.422	0.586	1.008	0.678	0.399
	70	0.297	0.697	0.994	0.606	0.233
	100	0.187	0.521	0.707	0.331	0.173
	150	0.121	0.293	0.414	0.194	0.075

Tab. 2 - continued

Station TETHYS

Date	m	Chl a	Phaeop.	Chl a + Phaeop.	Chl (monochr.)	Caroten.
16/01/95	0	2.743	1.916	4.659	3.954	0.448
17/01/95	2	0.519	2.138	2.657	1.426	0.115
18/01/95	0	0.635	0.548	1.183	0.912	0.664
	3	0.689	2.196	2.885	1.597	0.570
	9	0.872	2.711	3.583	2.281	1.086
19/01/95	0	0.709	0.656	1.365	1.141	-
	3	1.298	1.907	3.205	2.053	-
	20	0.594	2.387	2.980	1.825	-
21/01/95	3	0.853	2.298	3.151	1.688	0.904
	15	0.402	1.630	2.032	1.129	-
23/01/95	3	0.940	1.380	2.320	1.768	-
	15	0.473	1.265	1.738	1.186	-
25/01/95	3	0.969	1.395	2.364	1.631	-
	15	0.908	1.321	2.230	1.688	-
26/01/95	2	0.940	1.586	2.526	1.703	-
	15	0.678	1.374	2.052	1.426	-
27/01/95	3	0.933	2.365	3.298	1.711	-
	15	0.984	2.030	3.014	1.699	-
30/01/95	3	0.946	2.076	3.022	1.814	1.424
	15	0.069	1.623	1.691	0.616	-
08/02/95	0	0.413	0.442	0.855	0.433	0.314
	5	0.441	0.492	0.933	0.513	0.306
	10	0.498	0.615	1.113	0.536	0.371
	25	0.476	0.976	1.452	0.878	0.487
	50	0.475	0.800	1.275	0.787	0.401
	70	0.311	0.609	0.920	0.570	0.277
	100	0.259	0.460	0.719	0.365	0.161
	150	0.240	0.490	0.730	0.342	0.146
09/02/95	5	0.405	0.569	0.974	0.650	0.347

Tab. 3 - Phytoplankton pigments concentrations (mg/m^3) at TETHYS

Station GERLA

Date	m	Chl a	Phaeop.	Chl a + Phaeop.	Chl (monochr.)	Caroten.
21/01/95	3	0.321	1.119	1.440	0.798	0.369
	15	0.283	1.556	1.839	1.084	0.522
23/01/95	3	0.681	0.683	1.364	1.129	0.872
	15	0.978	1.573	2.551	2.030	1.583
25/01/95	3	2.379	1.866	4.245	3.319	2.150
	15	1.200	2.533	3.733	2.760	1.817
27/01/95	3	0.915	1.930	2.845	2.190	1.308
	15	1.315	2.397	3.712	2.487	1.621
30/01/95	0	1.835	1.088	2.923	2.179	2.081
	3	1.798	1.703	3.502	1.061	1.409
	15	0.495	1.274	1.768	2.179	0.618
04/02/95	2	1.326	1.060	2.386	2.019	1.503
05/02/95	3	0.466	0.847	1.313	0.810	0.561
	15	0.593	1.066	1.659	1.049	0.698

Tab. 4 - Phytoplankton pigments concentrations (mg/m^3) at GERLA

SYMPAGIC SAMPLES

date	m	Chl a	Phaeop.	Chl a + Phaeop.	Chl (monochr.)	Caroten.
bottom ice						
20/01/95		4146.6	1651.7	5798.4	4024.0	1964.6
		4207.2	1350.2	5557.4	5201.1	2586.0
23/01/95		8675.8	683.2	9359.0	7076.3	3580.2
surface ice						
08/02/95		1254.1	13.465	1267.6	1060.8	655.6
interior ice						
10/02/95		1075.8	368.76	1444.6	1085.9	403.0

Tab. 5 - Phytoplankton pigments concentrations (mg/m^3) in the sea ice with sympagic microalgae

Date	m	a (m^{-1}) 440 nm
Station TIBURTINA		
22/01/95	0	0.0071
	5	0.0065
	10	0.0064
	19	0.0060
	25	0.0060
	50	0.0046
	70	0.0033
	100	0.0049
	150	0.0070
24/01/95	0	0.0066
	5	0.0063
	10	0.0064
	12	0.0065
	25	0.0050
	50	0.0067
	70	0.0036
	100	0.0046
	150	0.0038
26/01/95	0	0.0042
	5	0.0054
	10	0.0029
	25	0.0051
	50	0.0065
	150	0.0028
28/01/95	5	0.0037
	10	0.0105
	19	0.0091
	70	0.0072

Date	m	a (m^{-1}) 440 nm
Station TIBURTINA		
03/02/95	0	0.0069
	5	0.0027
	10	0.0023
	25	0.0087
	30	0.0035
	50	0.0043
	70	0.0026
	100	0.0041
	150	0.0025
04/02/95	0	0.0020
	10	0.0039
08/02/95	0	0.0038
09/02/95	0	0.0016
12/02/95	0	0.0063
	5	0.0075
	10	0.0080
	25	0.0087
	50	0.0079
	70	0.0074
	100	0.0078
	150	0.0064

Tab. 6 - Absorption coefficient at 440 nm of dissolved organic matter

	Size Range	2.8 to 90.3 µm	2.8 to 90.3 µm	3.5 to 42.3 µm	2.8 to 90.3 µm	3.5 to 42.3 µm
Station BAIA TERRA NOVA						
Date	**m**	**Ncor./cm³**	**N/cm³**	**N/cm³**	**ppb**	**ppb**
17/01/95	0	5906	3158	2062	947	418
18/01/95	0	11456	6232	5923	1979	1386
19/01/95	0	7451	3586	3468	4123	1031
20/01/95	0	4706	2376	2266	1883	615
21/01/95	0	9604	4864	5388	1880	1171
22/01/95	0	7349	3668	2831	975	425
23/01/95	0	10947	5734	5793	1661	1193
Station TIBURTINA						
Date	**m**	**Ncor./cm³**	**N/cm³**	**N/cm³**	**ppb**	**ppb**
21/01/95	0	2884	1464	1937	1587	455
22/01/95	0	2253	1150	919	226	157
	5	13875	6581	5953	174	1011
	10	4309	2215	2111	829	456
	19	5923	3097	3260	1085	798
	25	3967	2010	2357	1274	858
	50	9066	4706	5124	1805	1379
	70	4810	2433	2437	984	713
	100	5161	2576	2658	1259	802
	150	3590	1889	1920	630	400
23/01/95	0	9264	4375	4300	1422	1063
Station TETHYS						
Date	**m**	**Ncor./cm³**	**N/cm³**	**N/cm³**	**ppb**	**ppb**
18/01/95	0	6784	3234	2282	1761	144
	3	3333	1707	1419	2349	580
	9	4481	2331	2317	1268	720
19/01/95	0	4988	2454	2111	1125	704
	3	6157	3184	3215	1912	1087
	20	2433	1262	652	627	387
21/01/95	3	5126	2291	2266	2281	1022
	15	5546	2717	1997	1795	721
23/01/95	3	9873	4769	5944	2136	1601
	15	4660	2351	2588	915	618
Station GERLA						
date	**m**		**N/cm³**	**N/cm³**	**ppb**	**ppb**
20/01/95	symp.	1352576	613056	572400	560000	400000
21/01/95	3	3682	1591	1178	643	440
	15	4069	1987	1998	830	481
23/01/95	3	5172	2403	2238	2028	793
	15	8500	4209	2051	3970	1479

Tab. 7 - Particles density (N/cm^3) and volume (ppb)

			ex/em	440 nm/684 nm	
Date	Stn.	m	F0	Fmax	Fv
17/01/95	BTN	0	4,250	5,17	0,178
18/01/95	BTN	0	6,250	7,214	0,134
19/01/95	BTN	0	4,260	6,134	0,306
01/02/95	BTN	0	1,811	2,213	0,182
06/02/95	BTN	0	1,686	-	-
22/01/95	Tib	5	0,407	0,829	0,509
		10	0,268	0,384	0,302
		19	5,217	7,465	0,301
		50	0,755	0,904	0,165
28/01/95	Tib	5	3,602	4,139	0,130
		10	3,065	4,141	0,260
		20	3,195	4,311	0,259
		70	1,351	1,454	0,071
03/02/95	Tib	5	1,910	2,201	0,132
		10	1,446	2,439	0,407
		30	0,933	1,391	0,329
		50	0,268	0,418	0,359
04/02/95	Tib	10	2,188	3,186	0,313
09/02/95	Tib	10	0,736	1,255	0,414
18/01/95	Tethys	0	0,528	0,609	0,133
		3	0,908	0,933	0,027
		10	1,063	1,071	0,007
19/01/95	Tethys	0	0,547	0,802	0,317
		3	0,833	1,043	0,202
		20	0,814	1,132	0,281
08/02/95	Tethys	0	0,496	1,670	0,703
	Tethys	symp.	231,83	255,88	0,094
20/01/95	Gerla	symp.	200,00	190,00	-0,053
23/01/95	Gerla	symp.	160,00	159,00	-0,006
10/02/95	Campbell	symp.	8,167	8,253	0,010

Tab. 8 - Variable fluorescence measurements (r.u.)

Date	Stn.	m.	% of surface quanta	incubation time.	mg C/m³h	mgC/mgchl h	ex/em 440nm/684nm F0	Fmax	Fv
04/02/95	Tib	10	dark	7h	0.277	0.15	-	-	-
04/02/95	Tib	10	dark	7h	0.034	0.02	-	-	-
04/02/95	Tib	10	0.53	7h	3.530	1.96	1.737	2.802	0.380
04/02/95	Tib	10	0.67	7h	3.715	2.06	1.436	2.576	0.443
04/02/95	Tib	10	0.83	7h	3.962	2.20	1.766	2.674	0.340
04/02/95	Tib	10	1.04	7h	4.642	2.58	1.580	2.614	0.395
04/02/95	Tib	10	1.30	7h	4.719	2.62	1.461	2.859	0.489
04/02/95	Tib	10	8.00	7h	2.963	1.64	1.675	2.081	0.195
04/02/95	Tib	10	8.00	3h	4.290	2.38	1.006	2.559	0.607
04/02/95	Tib	10	40.00	7h	2.624	1.46	1.610	1.890	0.150
04/02/95	Tib	10	40.00	3h	3.451	1.92	1.579	2.509	0.371
06/02/95	BTN	0	dark	7h	0.128	0.12	-	-	-
06/02/95	BTN	0	dark	3h	0.161	0.15	-	-	-
06/02/95	BTN	0	0.53	7h	1.340	1.24	-	-	-
06/02/95	BTN	0	0.67	7h	2.418	2.24	-	-	-
06/02/95	BTN	0	0.83	7h	2.205	2.04	-	-	-
06/02/95	BTN	0	1.04	7h	1.362	1.26	-	-	-
06/02/95	BTN	0	1.30	7h	1.782	1.65	-	-	-
06/02/95	BTN	0	8.00	7h	1.900	1.76	-	-	-
06/02/95	BTN	0	8.00	3h	3.054	2.83	0.542	0.891	0.392
06/02/95	BTN	0	40.00	7h	2.553	2.36	-	-	-
06/02/95	BTN	0	40.00	3h	1.580	1.46	0.699	0.861	0.189
08/02/95	symp.		dark	3h	15.54	0.01	-	-	-
08/02/95	symp.		1.30	3h	549.98	0.52	-	-	-
08/02/95	symp.		8.00	3h	522.41	0.49	-	-	-
08/02/95	symp.		40.00	3h	383.64	0.36	-	-	-
08/02/95	Tethys	0	dark	3h	0.014	0.03	-	-	-
08/02/95	Tethys	0	1.30	3h	0.766	1.77	-	-	-
08/02/95	Tethys	0	8.00	3h	0.825	1.91	-	-	-
08/02/95	Tethys	0	40.00	3h	0.806	1.86	-	-	-

Tab. 9 - Incubation experiments: primary production and variable fluorescence (r.u.).

Date	Stn.	m	% of surface quanta	incubation time	treatment	ex/em 440nm/684nm F0	Fmax	Fv
09/02/95	Tib	10	40.00	0h	control	0.736	1.255	0.414
			40.00	24h	control	0.466	1.432	0.674
			40.00	24h	Fe added	0.595	1.213	0.509
			40.00	48h	control	0.570	2.044	0.721
			40.00	48h	Fe added	0.865	2.120	0.592
			40.00	72h	control	0.408	0.680	0.401
			40.00	72h	Fe added	0.795	1.057	0.248

Tab. 10 - Fe incubation experiments: variable fluorescence measurements (r.u.)

Tables 11-15

Surface phytoplankton density (cell/dm^3)
at the sampled stations

	14.01.95	18.01.	22.01.	26.01.
Achnanthes sp.	0	0	4561	0
Amphiprora cf. kufferathii	0	0	3258	0
Asteromphalus heptactis	0	0	1303	0
Asteromphalus hookerii	0	0	0	0
Asteromphalus hyalinus	0	0	0	0
Centric diatoms < 20 µm	879	19007	5864	28927
Centric diatoms > 20 µm	879	0	0	0
Chaetoceros cf. 'bulbosum complex'	0	792	0	877
Chaetoceros cf. neglectus	0	0	0	0
Chaetoceros cf. neogracile	0	0	0	438
Chaetoceros spp.	0	0	652	438
Cocconeis imperatrix	0	0	0	0
Cylindrotheca closterium	2637	9503	0	10519
Dactyliosolen tenuijunctus	0	0	6515	12272
Eucampia antarctica	0	0	0	0
Fragilariopsis cf. curta	336696	1701882	123788	860346
Fragilariopsis cf. ritscheri	0	0	652	0
Fragilariopsis spp. (girdle view)	1718644	3148759	598741	1171087
Licmophora spp.	14945	7127	6515	3068
Melosira sp. 15 µm	0	79194	21500	10080
Navicula sp. 20 µm	8791	24550	92515	8327
Nitzschia cf. subcurvata	1758	11087	1955	24982
Nitzschia sp. (bilobatae sec.)	10549	0	5212	877
Nitzschia sp. 75 µm	0	0	2606	0
Nitzschia spp.	0	0	0	1753
Odontella weissflogii	0	0	0	0
Pennate diatom sp. 7 µm	0	0	0	0
Pennate diatoms spp.	3516	10295	7818	3068
Pseudonitzschia spp.	0	3168	652	3068
Rhizosolenia cf. hebetata	0	0	0	0
Rhizosolenia truncata	0	0	0	0
Thalassiosira cf. antarctica	0	0	0	0
Thalassiosira spp. (< 20 µm)	0	0	0	0
Thalassiosira spp. (> 20 µm)	0	0	0	0
Thalassiothrix antarctica	0	0	0	0
Amphidinium cf. longum	0	0	0	0
Amphidinium sp. a (37 µm)	0	2376	0	438
Amphidinium sp. b (9 µm)	0	4752	0	877
Amphidinium sp. c (39 µm)	1758	2376	0	0
Dinophysis cf. contracta	879	0	0	0

Table 11 - St. Baia Terra Nova. Surface phytoplankton density (cell/dm^3)

	14.01.95	18.01.	22.01.	26.01.
Gymnodiniaceae < 20 µm	14066	792	7818	4383
Gymnodiniaceae > 20 µm	6154	0	652	2191
Gymnodinium cf. frigidum	0	0	0	0
Gymnodinium cf. guttula	5275	7919	1303	1315
Gymnodinium sp. a (10 µm)	34285	21382	3258	7012
Gymnodinium sp. b (13 µm)	7912	6336	0	438
Gymnodinium sp. d (27 µm)	25494	16631	0	1315
Gymnodinium sp. e (12 µm)	1758	10295	652	877
Gyrodinium lachryma	1758	9503	652	1753
Gyrodinium spp. (> 20 µm)	0	0	0	0
Naked dinoflagellates < 20 µm	0	6336	652	3506
Naked dinoflagellates > 20 µm	0	0	0	2630
Prorocentrum cf. antarcticum	2637	33262	5864	16216
Protoperidinium antarcticum	0	0	0	0
Protoperidinium applanatum	0	792	1955	877
Protoperidinium cf. archiovatum	0	0	0	0
Protoperidinium cf. bellulum	879	792	0	438
Protoperidinium defectum	41318	17423	3909	1315
Protoperidinium cf. incertum	7033	0	652	1753
Protoperidinium cf. mediocre	0	0	0	0
Protoperidinium cf. rosaceum	0	0	0	0
Thecate dinoflagellates < 20 µm	0	1584	0	3068
Thecate dinoflagellates > 20 µm	0	0	0	438
Thecate dinoflagellates (apical view)	10549	1584	652	1753
Unidentified dinoflagellates	3516	0	0	0
Cryptophyceans < 15 µm	79119	76818	9773	18408
Dictyocha speculum	0	6336	5212	438
Phytoflagellate sp. 1 (8 µm)	523945	69691	39742	41637
Phytoflagellate sp. 2 (10 µm)	16703	11087	8470	3068
Phytoflagellate sp. 12 µm	0	0	652	0
Phytoflagellates < 10 µm	43076	37221	2606	7451
Phytoflagellates < 20 µm	0	24550	0	0
Diatoms	2099296	5015365	884104	2140126
Dinoflagellates	165271	144133	28015	52594
Cryptophyceans	79119	76818	9773	18408
Phytoflagellates	583724	148885	56682	52594
TOTAL	2927410	5385201	978574	2263722

Tab. 11 - continued

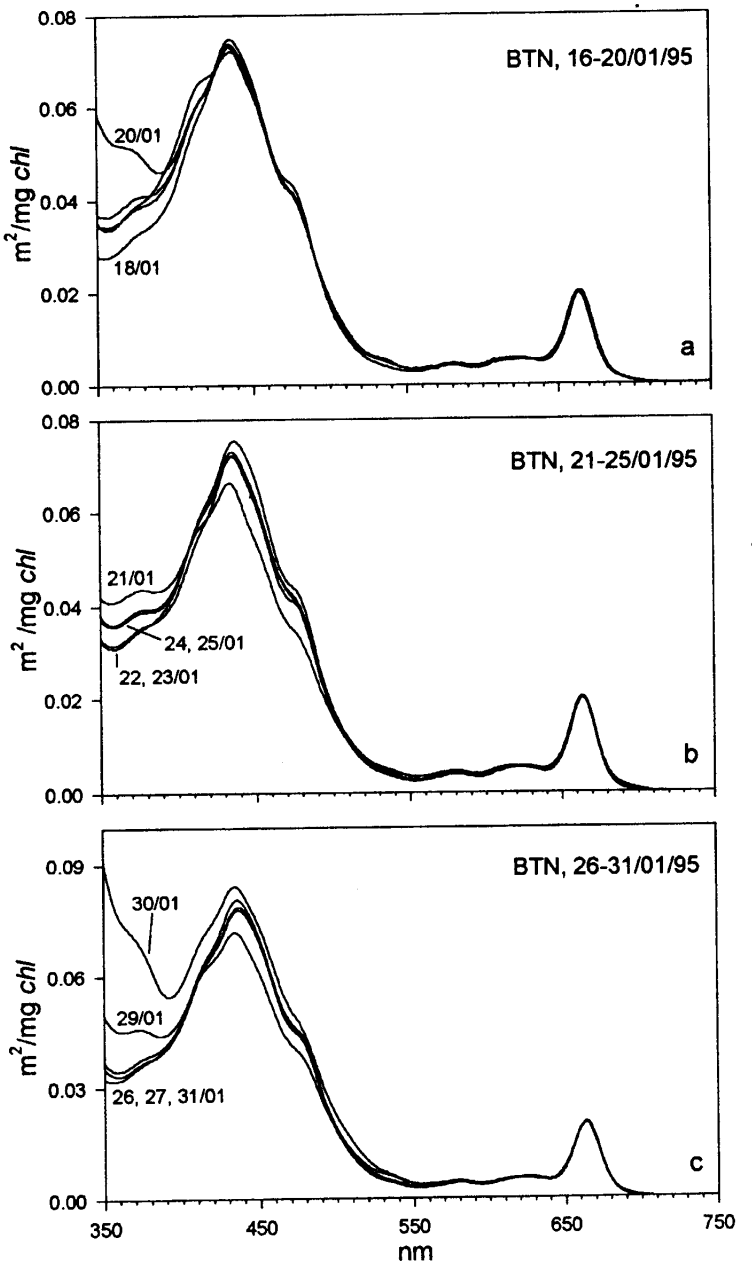


Fig. 1 - Specific absorption coefficient spectra (m^2/mg *chl*) of acetonic extracts of phytoplankton at BTN from 16.01.95 to 31.01.95

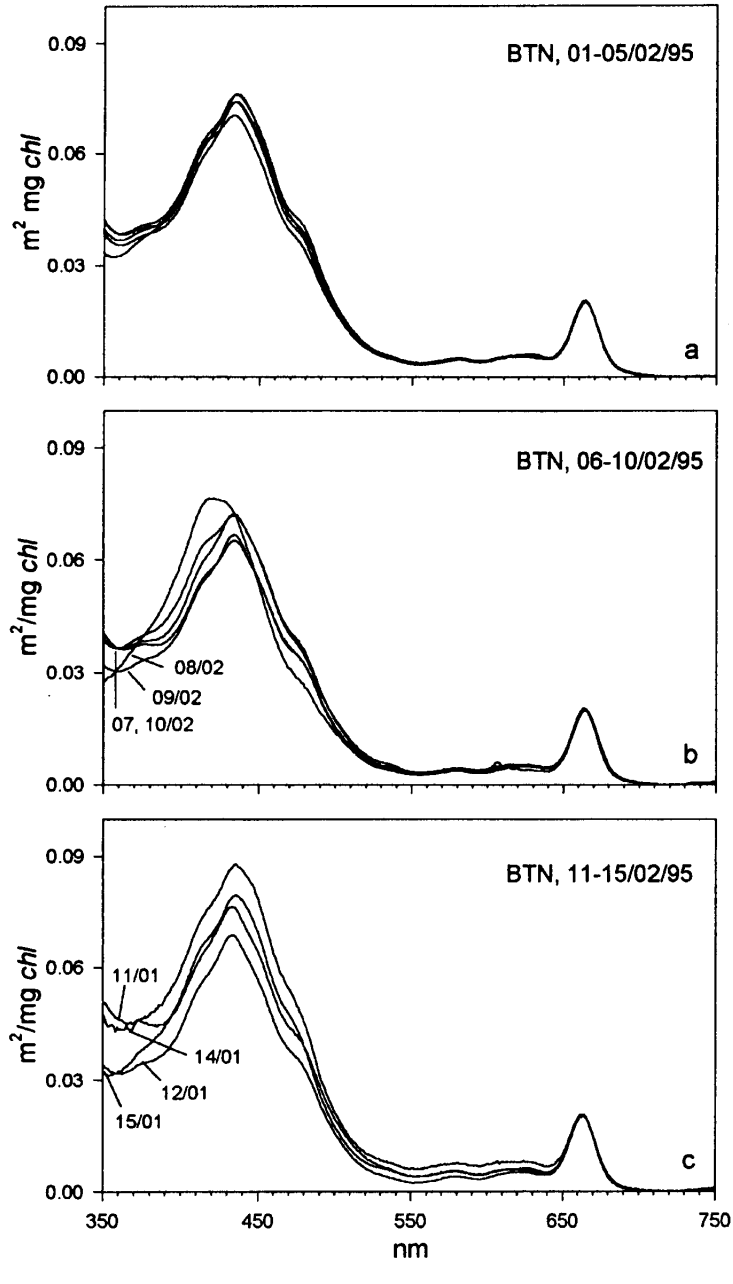


Fig. 2 - Specific absorption coefficient spectra (m^2/mg *chl*) of acetonic extracts of phytoplankton at BTN from 01.02.95 to 15.02.95

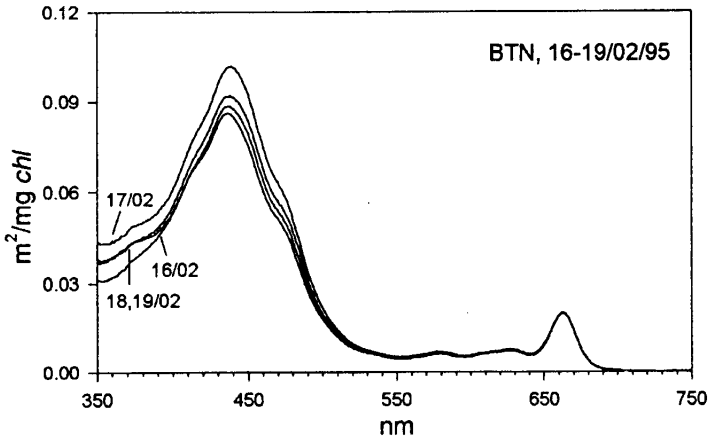


Fig. 3 - Specific absorption coefficient spectra (m^2/mg *chl*) of acetonic extracts of phytoplankton at BTN from 16.02.95 to 19.02.95

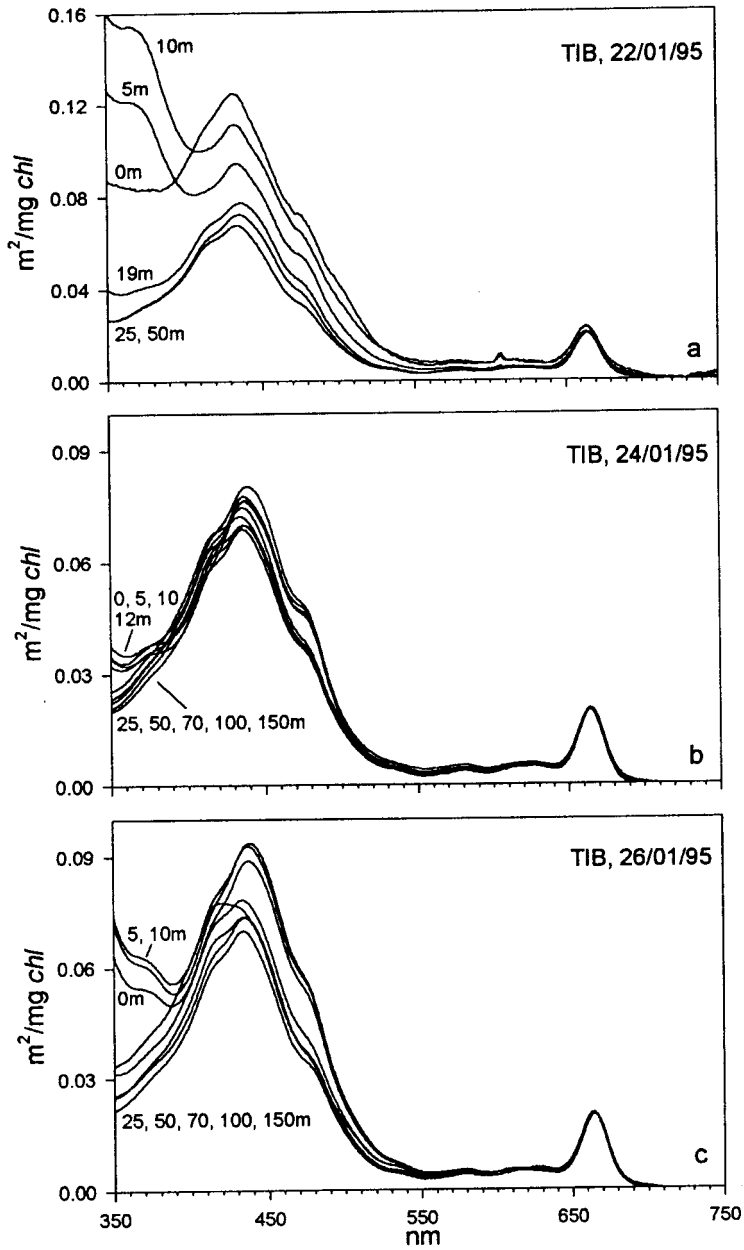


Fig. 4 - Specific absorption coefficient spectra (m^2/mg *chl*) of acetonic extracts of phytoplankton at TIB from 22.01.95 to 26.01.95

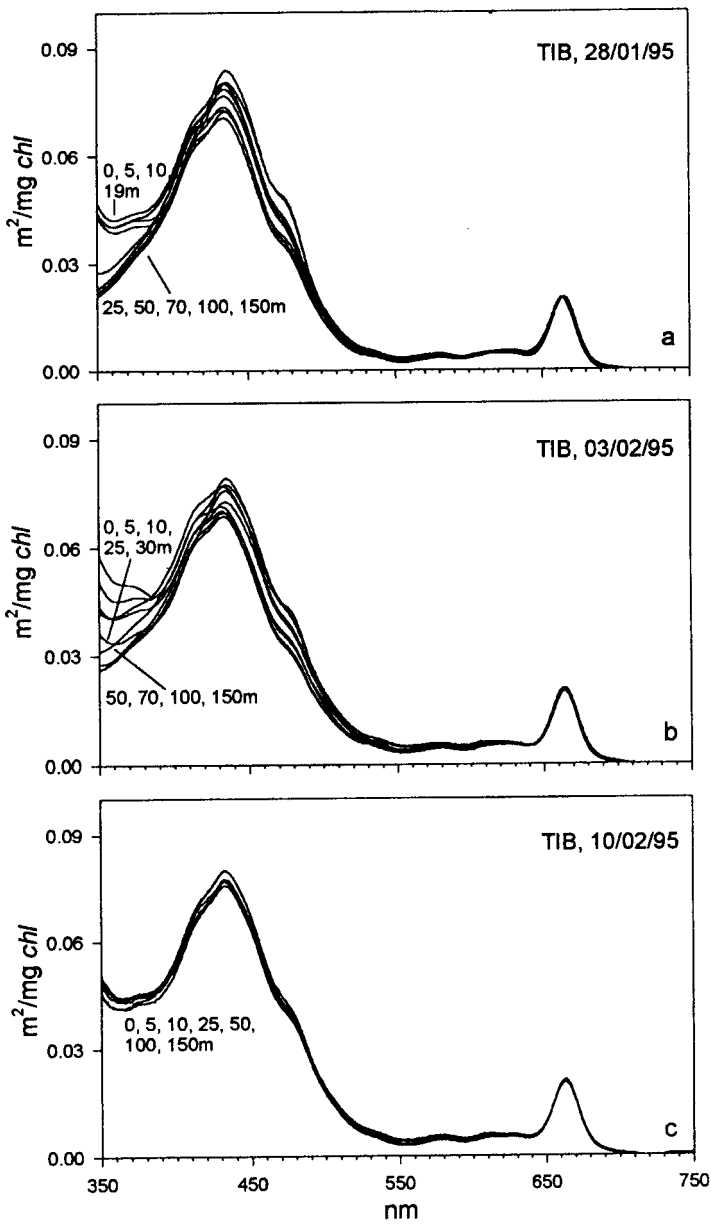


Fig. 5 - Specific absorption coefficient spectra (m²/mg *chl*) of acetonic extracts of phytoplankton at TIB from 28.01.95 to 10.02.95

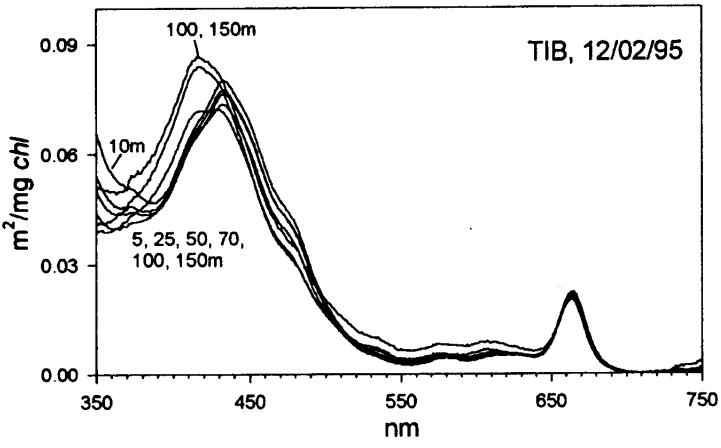


Fig. 6 - Specific absorption coefficient spectra (m²/mg *chl*) of acetonic extracts of phytoplankton at TIB 12.02.95

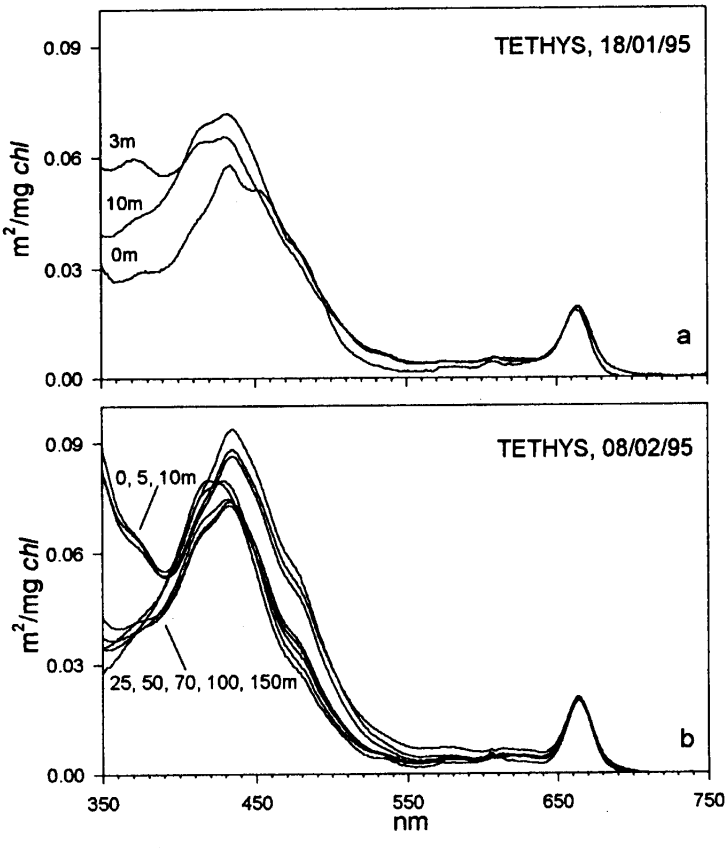


Fig. 7 - Specific absorption coefficient spectra (m²/mg *chl*) of acetonic extracts of phytoplankton at TETHYS 18.01.95 and 08.02.95

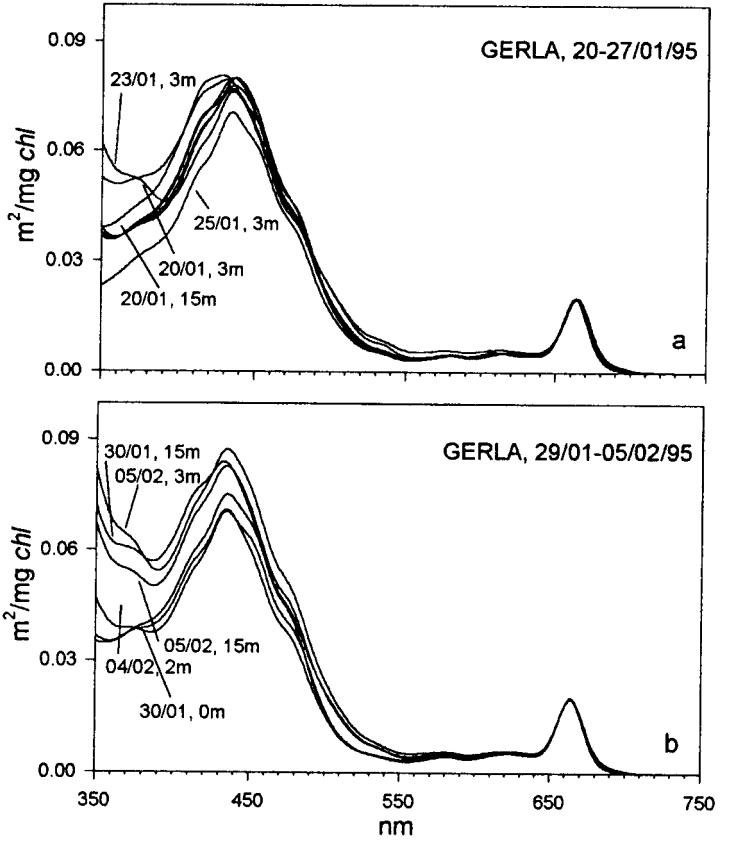
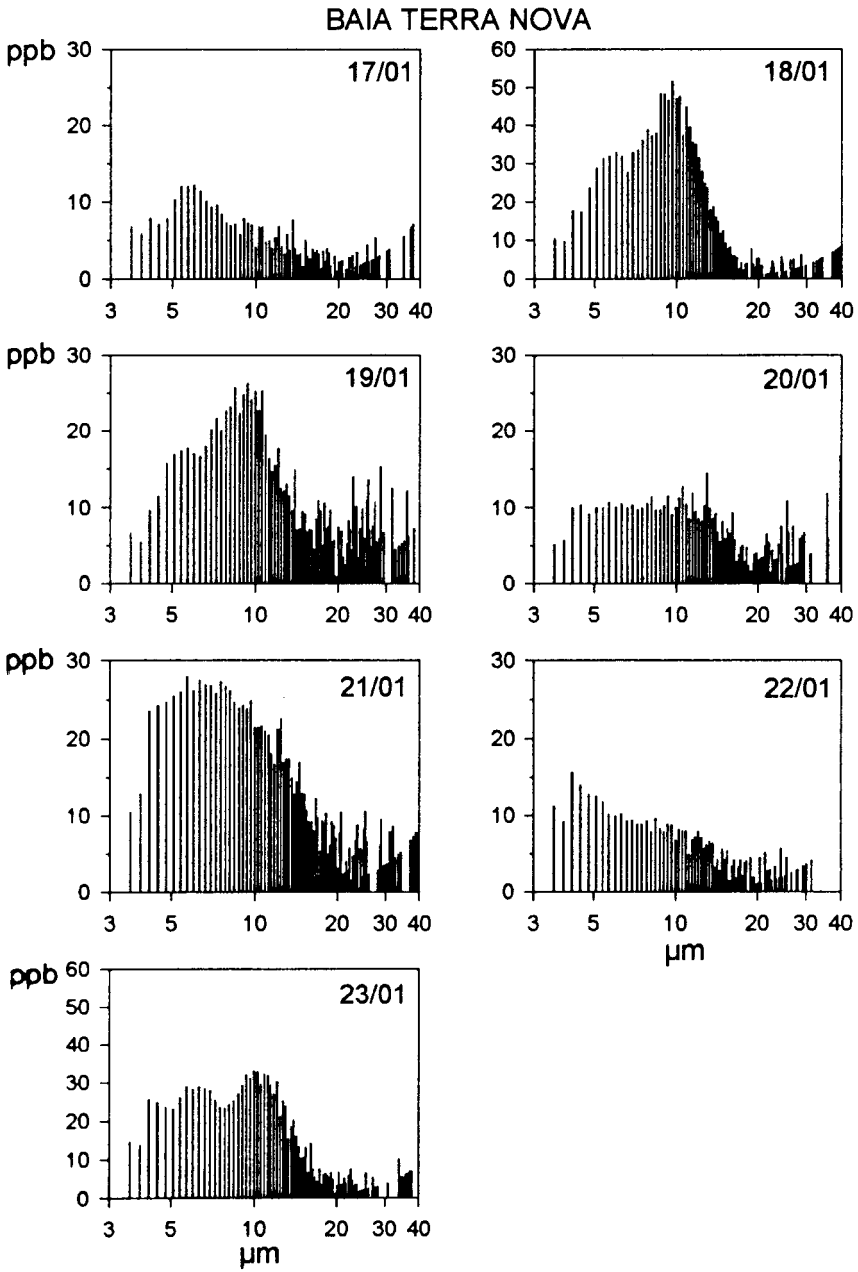


Fig. 8 - Specific absorption coefficient spectra (m^2/mg *chl*) of acetonic extracts of phytoplankton at GERLA from 20.01.95 to 05.02.95



Particles volume size spectra (ppb) at BTN

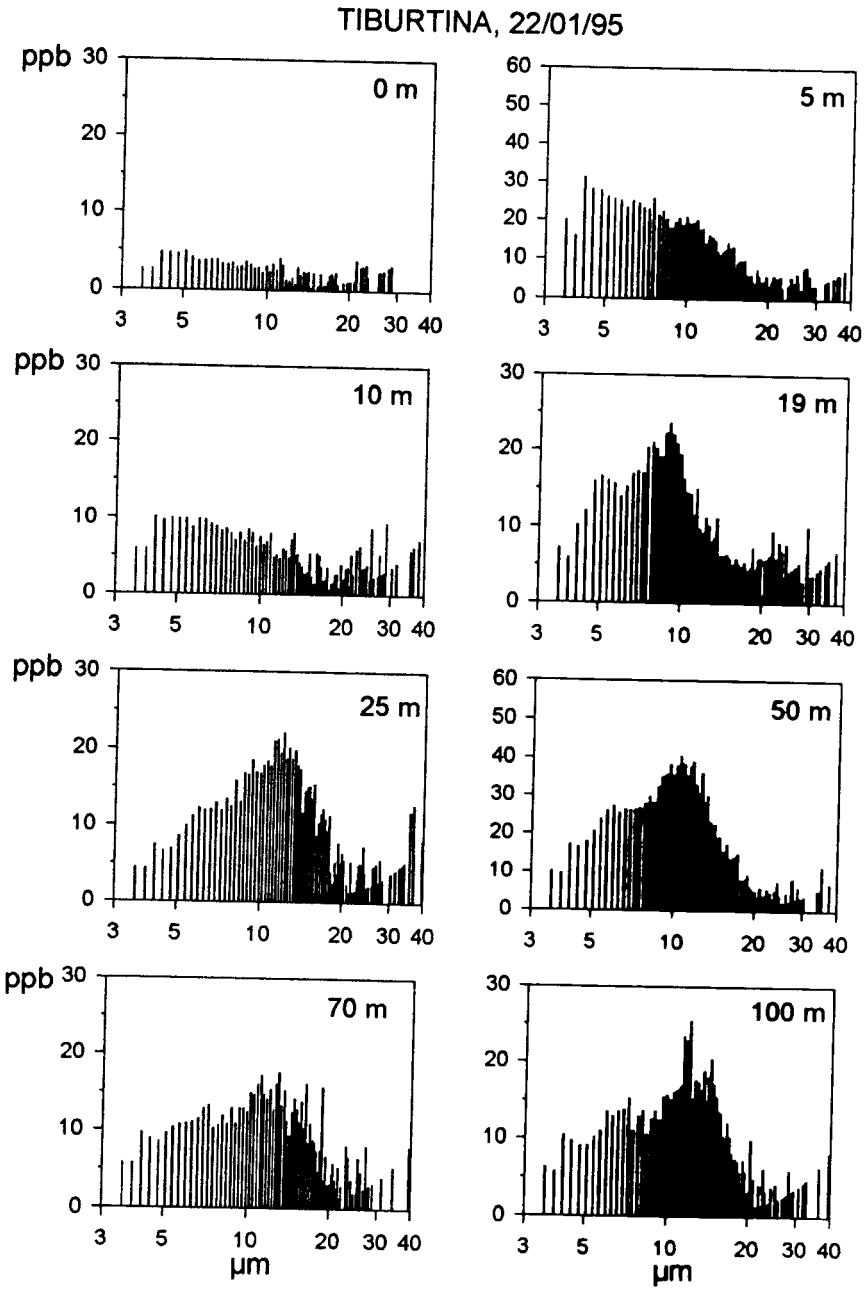


Fig. 10 - Particles volume size spectra (ppb) at TIB

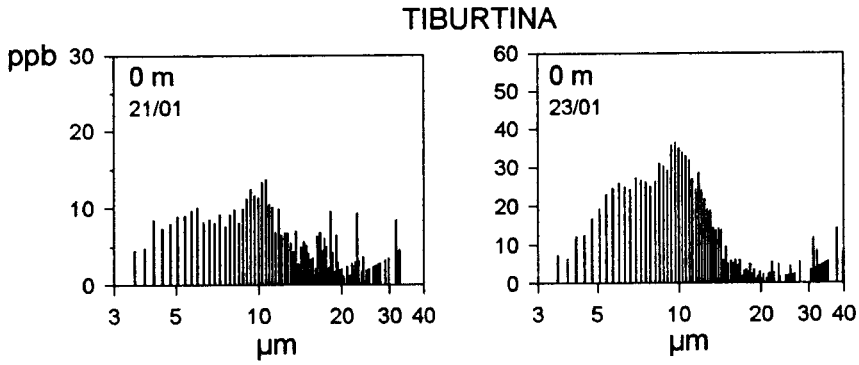


Fig. 11 - Particles volume size spectra (ppb) at TIB

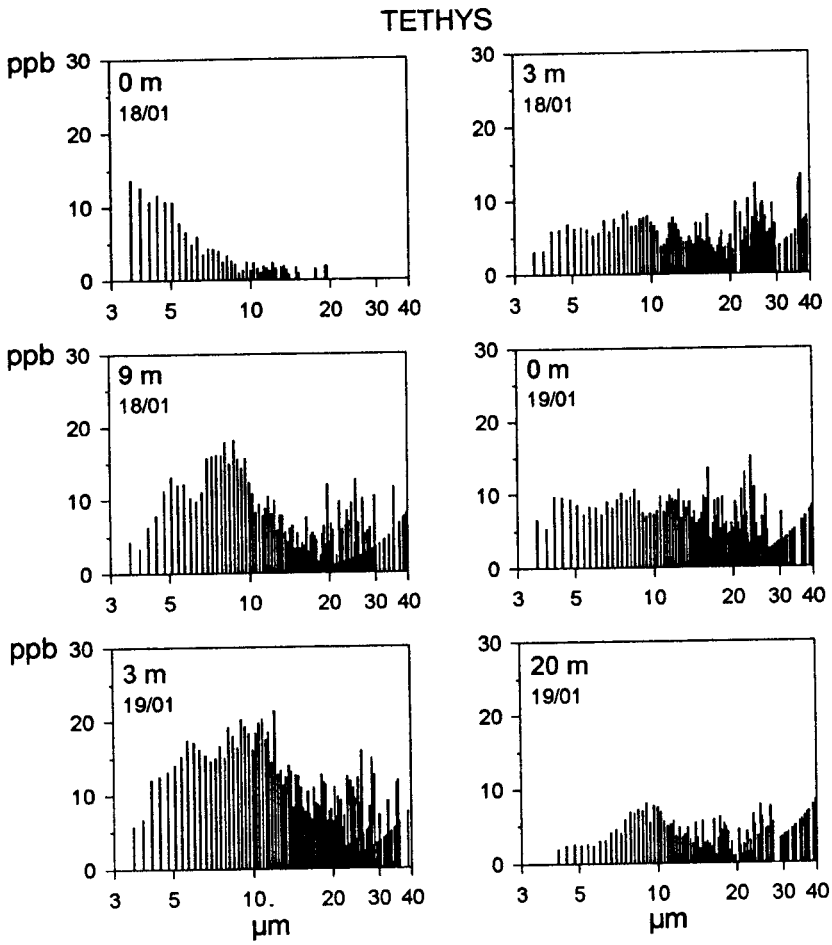


Fig. 12 - Particles volume size spectra (ppb) at TETHYS

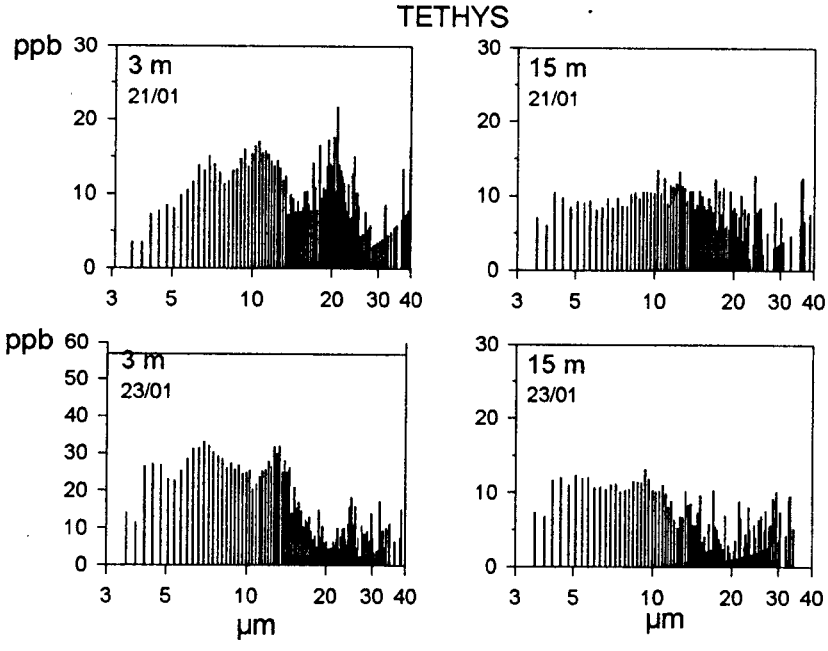


Fig. 13 - Particles volume size spectra (ppb) at TETHYS

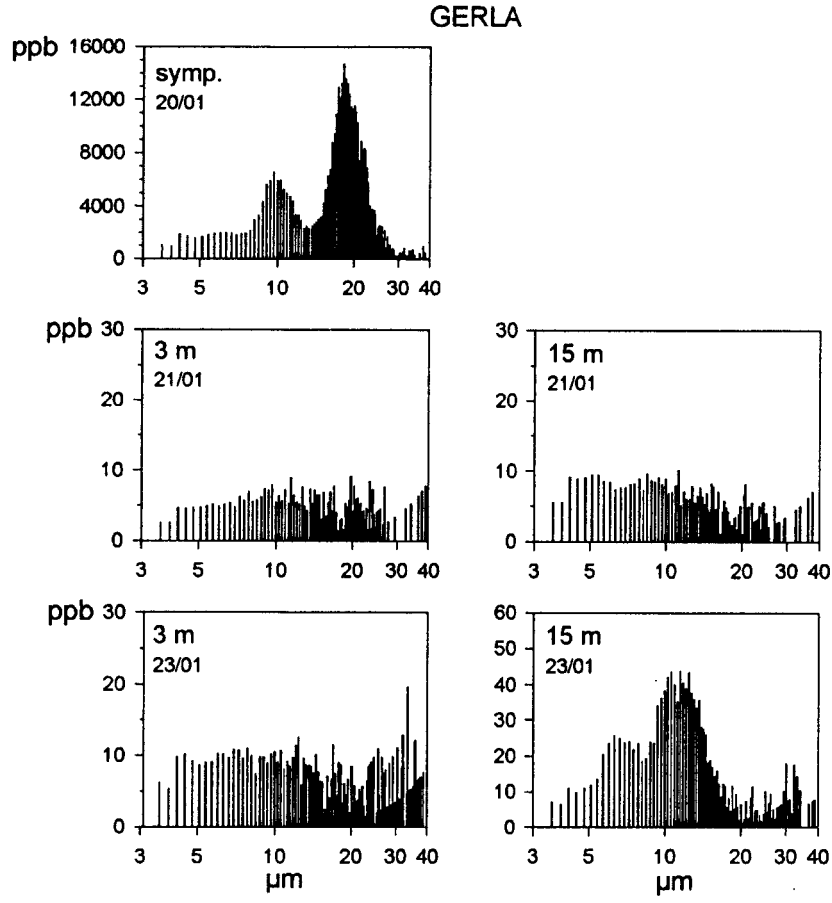


Fig. 14 - Particles volume size spectra (ppb) at GERLA

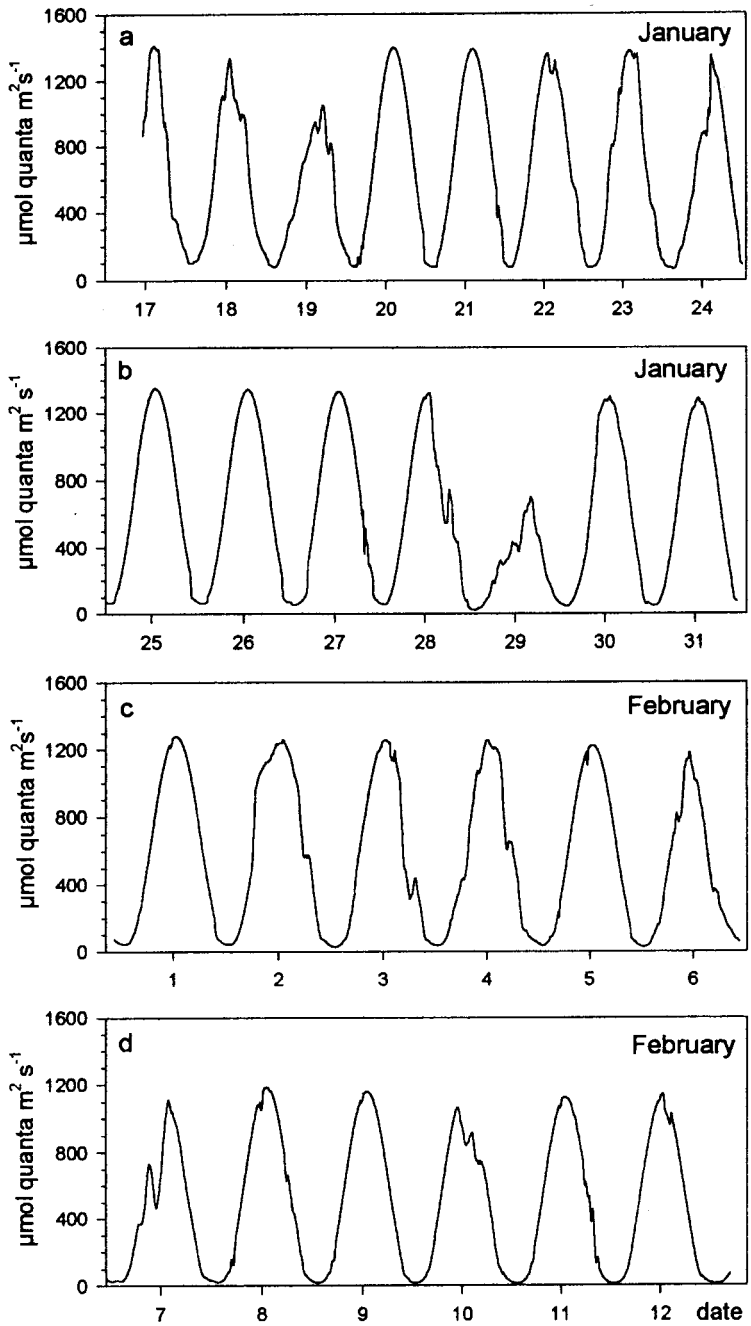


Fig. 15 - Continuous surface quantum PAR records at BTN. **a**,from 17.01.95 to 24.01.95; **b**, from 25.01.95 to 31.01.95; **c**, from 01.02.95 to 06.02.95; **d**, from 07.02.95 to 12.02.95

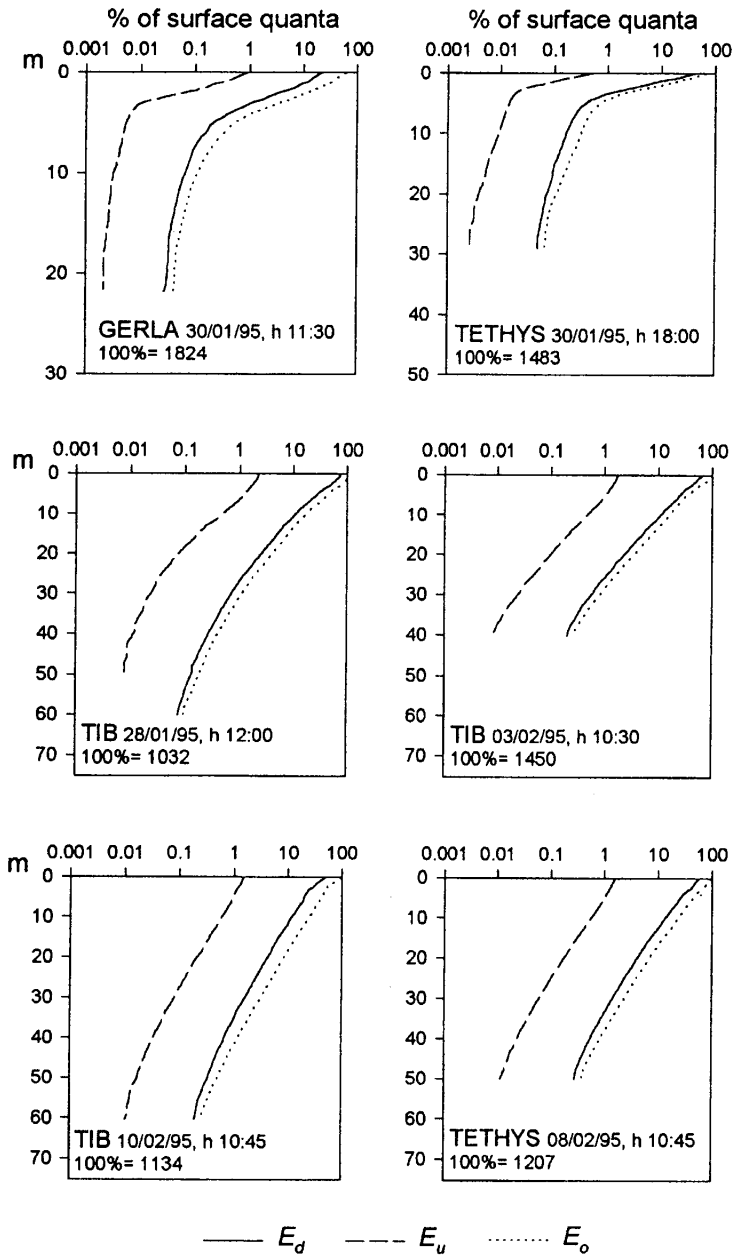


Fig. 16 - Vertical profiles of downwelling (E_d), upwelling (E_u), and scalar (E_o) quantum PAR irradiance as percentage of the downwelling surface irradiance, reported in μmol quanta/m^2 s, as 100%

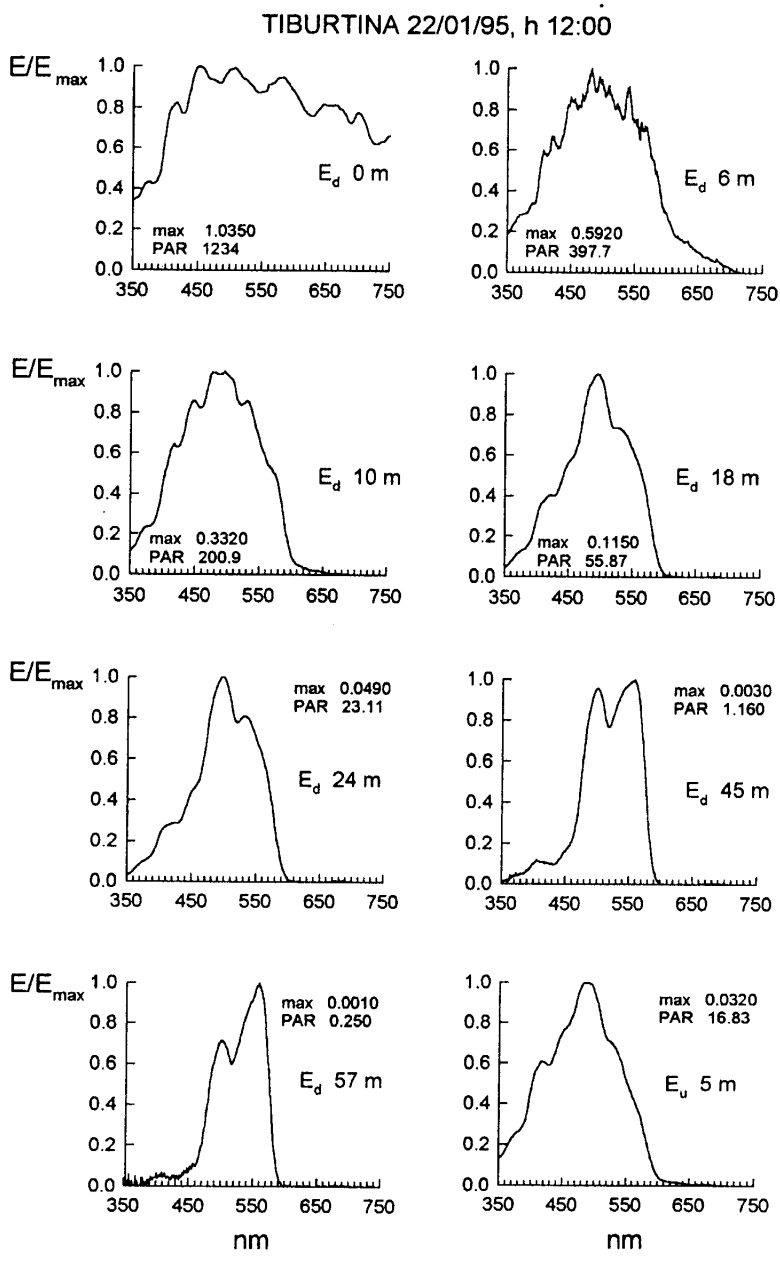


Fig. 17 - Surface and underwater downwelling (E_d) and upwelling (E_u) spectral irradiance normalized to its maximum (max, W/m² nm) at the indicated depth. The integrated quantum PAR irradiance (PAR, µmol quanta/m² s) is also reported

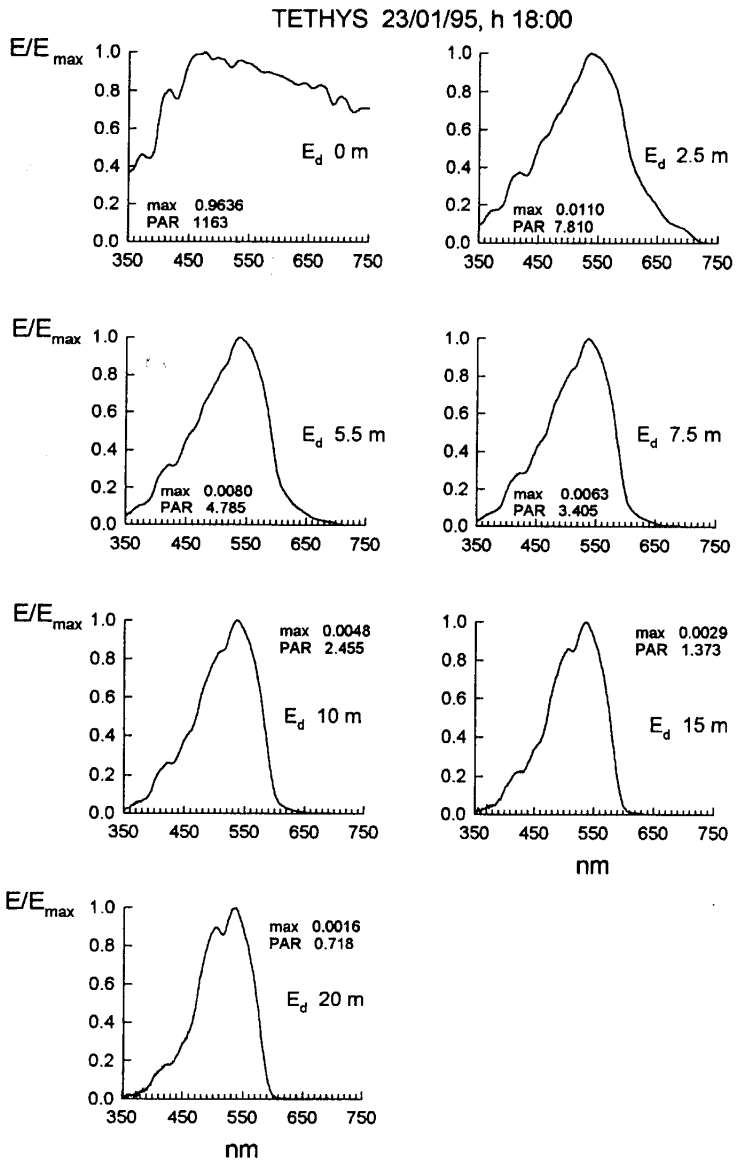


Fig. 18 - Surface and underwater downwelling (E_d) and upwelling (E_u) spectral irradiance normalised to its maximum (max, W/m² nm) at the indicated depth. The integrated quantum PAR irradiance (PAR, μmol quanta/m² s) is also reported

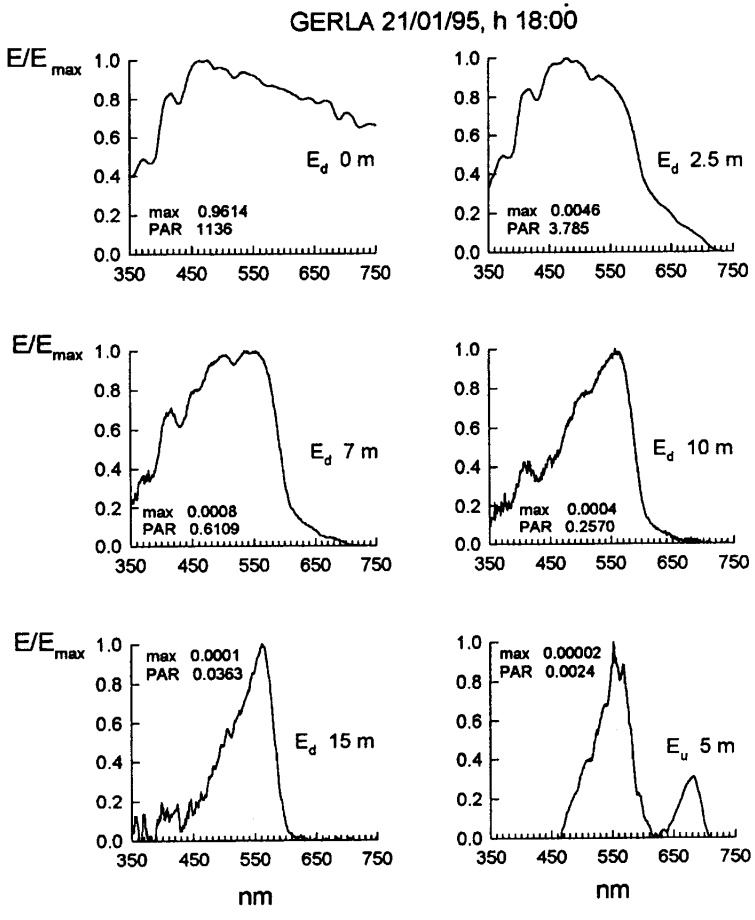


Fig. 19 - Surface and underwater downwelling (E_d) and upwelling (E_u) spectral irradiance normalised to its maximum (max, W/m² nm) at the indicated depth. The integrated quantum PAR irradiance (PAR, µmol quanta/m² s) is also reported.

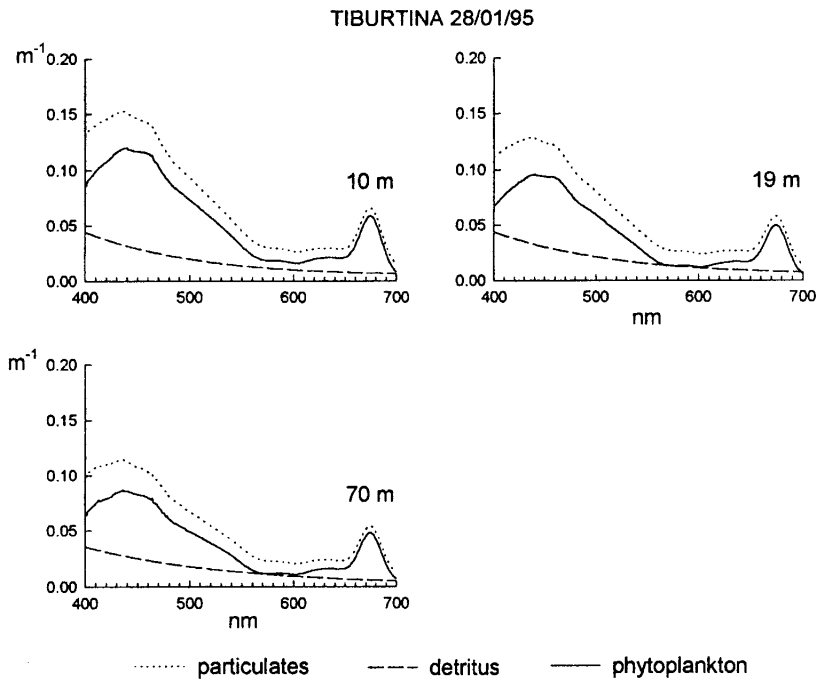


Fig. 20 - Absorption coefficient spectra (m^{-1}) of particulate matter, detritus and phytoplankton

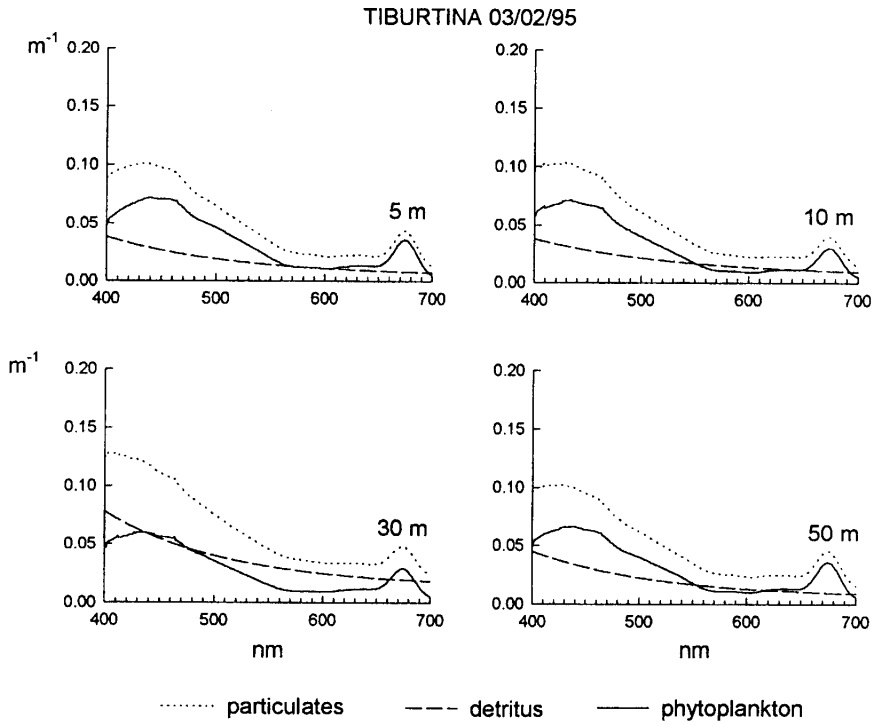


Fig. 21 - Absorption coefficient spectra (m^{-1}) of particulate matter, detritus and phytoplankton

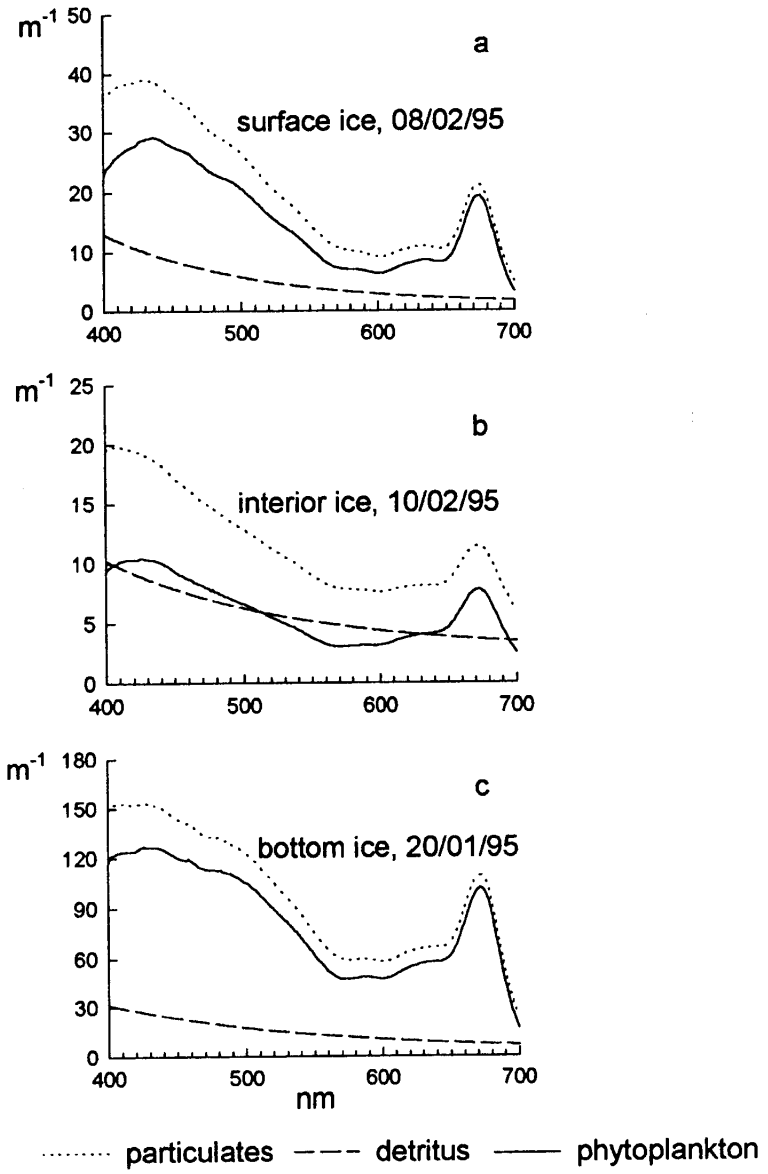


Fig. 22 - Absorption coefficient spectra (m^{-1}) of particulate matter, detritus and phytoplankton

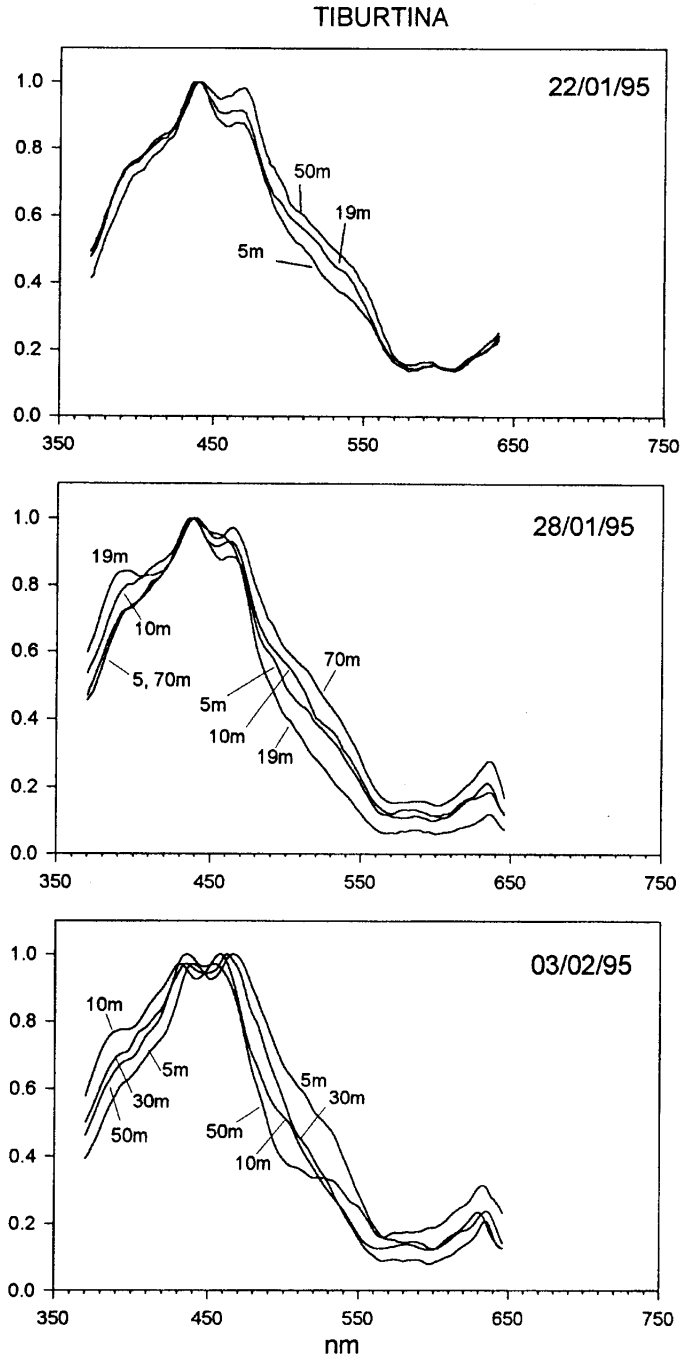


Fig. 23 - Fluorescence excitation spectra normalised to their maximum (em = 684 nm)

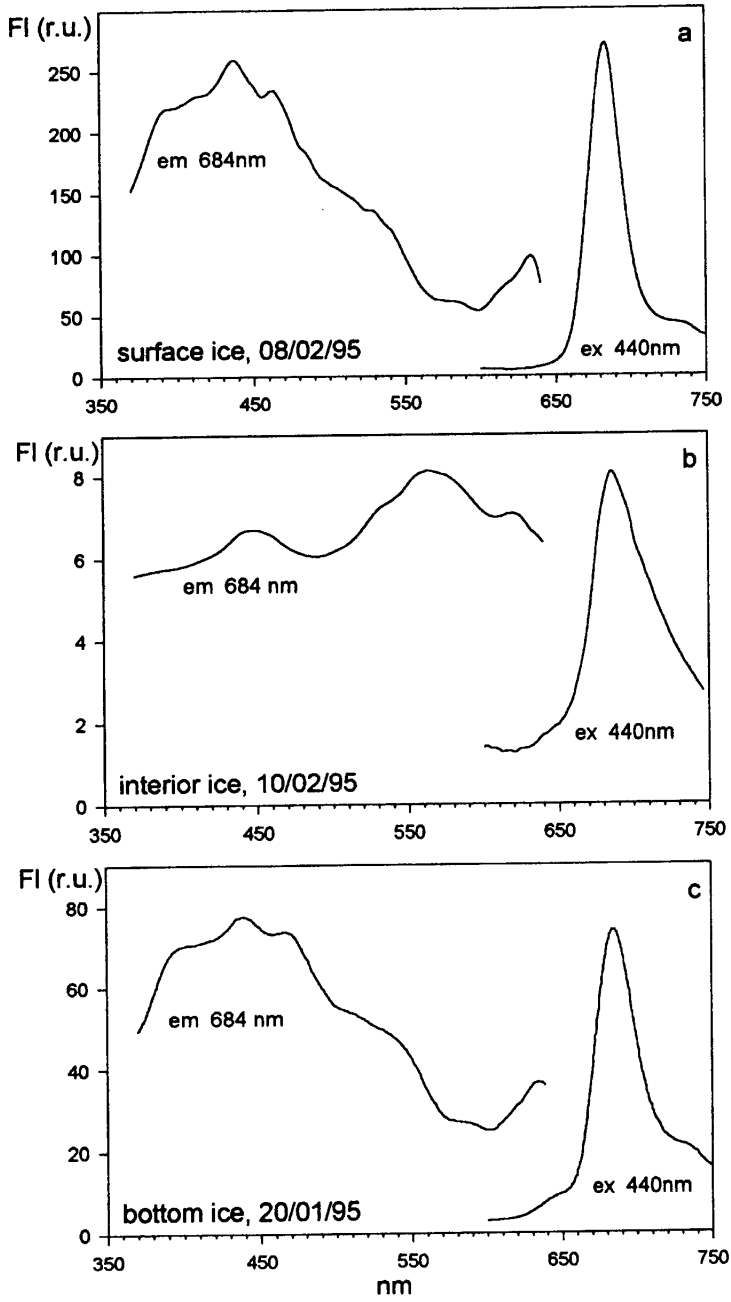


Fig. 24 - Fluorescence excitation and emission spectra (r.u.)

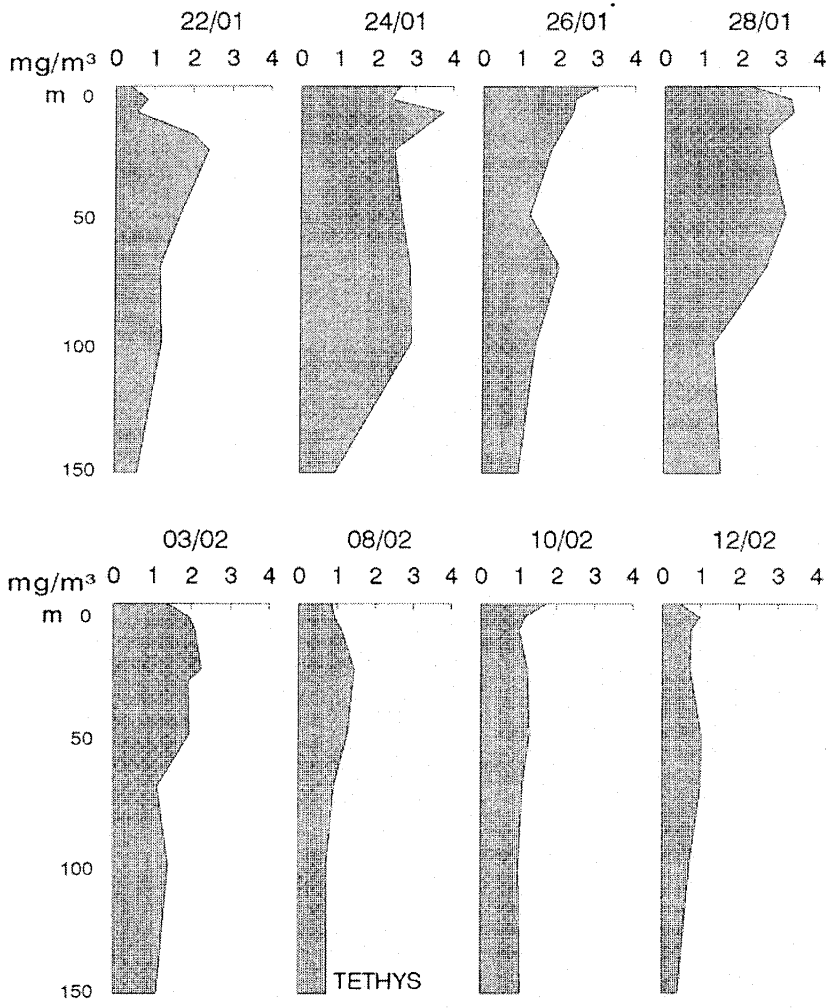


Fig. 25 - Vertical profiles of chlorophyll a + phaeopigments (mg/m³) at TIBURTINA and TETHYS without ice cover (08/02)

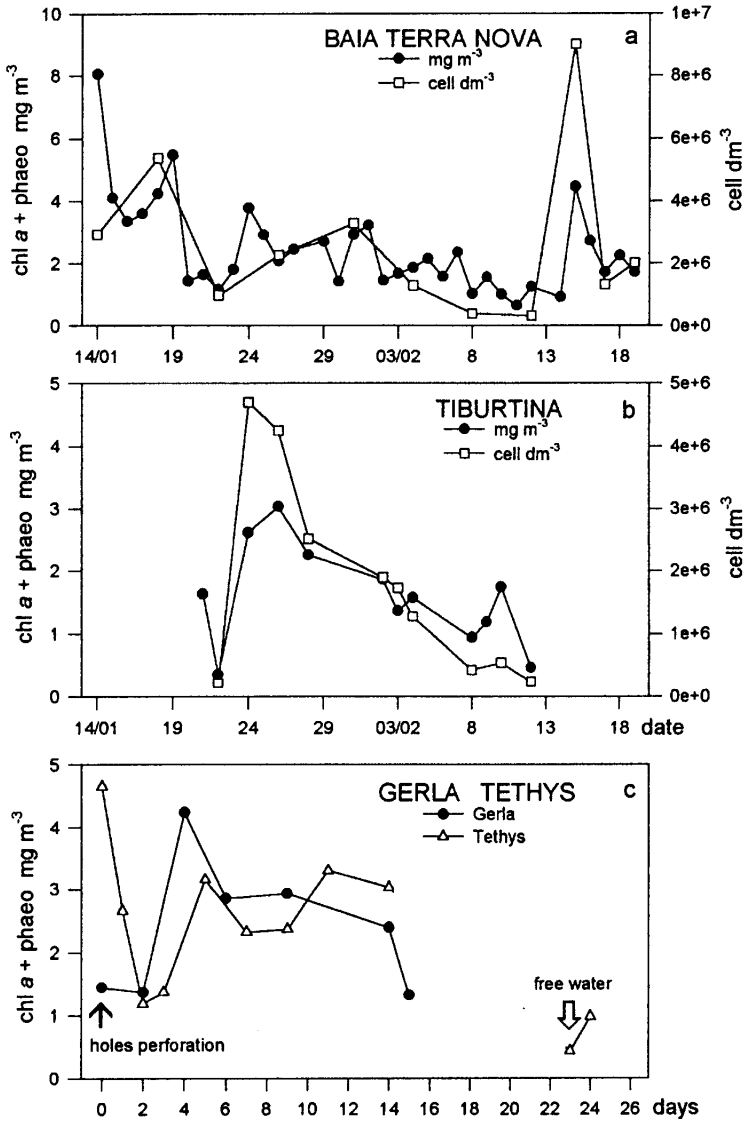


Fig. 26 - Temporal distributions of surface *chl* (mg/m³) and cell density (cell/dm³) at: **a**, BTN; **b**, TIBURTINA. **c**, temporal distribution of surface *chl* (mg/m³) at GERLA and TETHYS stations, the temporal scale represents the time lag from the perforation.